

The University of Chicago

THE GEOLOGY OF
HART TOWNSHIP, ONTARIO, AND
ADJACENT AREAS

A PART OF A DISSERTATION SUBMITTED
TO THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY
1936

By
TERENCE C. HOLMES

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS
1938

The University of Chicago

THE GEOLOGY OF
HART TOWNSHIP, ONTARIO, AND
ADJACENT AREAS

A PART OF A DISSERTATION SUBMITTED
TO THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY

1936

By

TERENCE C. HOLMES

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

1938



INTRODUCTION

The object of the field work upon which this thesis is based was to study the relations of the granitic rocks and Huronian sediments, found in the vicinity of Hart township, Ontario.¹ According to previous workers, Huronian sedimentary rocks, and pre-Huronian granite underlie the northern part of the area,² while sediments, presumed to be Huronian and post-Huronian granite underlie the southern part.³ An unmapped strip crossed the center of the area separating the parts examined by the previous workers. In the summer of 1934, the writer mapped this strip and remapped parts of the adjoining areas. The results of this work are shown on Figure 2.

General Statement

The oldest rocks in the area are a series of pre-Huronian gneisses and schists, found only along the southeastern border. The Huronian sediments, the next younger rocks, occupy four areas separated from each other and from the pre-Huronian by rocks of a later intrusive, the Birch Lake batholith of Killarney age, which intrudes both of the groups of older rocks and underlies by far the greater part of the area. It completely surrounds at least three of the areas of Huronian sediments, separating each of them from other pre-Killarney rocks by several miles. Either before or during the intrusion, the Huronian sediments were greatly deformed and as a result are nearly vertical in most places. The

¹The area examined is shaded in Figure 1. It lies northwest of the Sudbury basin.

²F. F. Osborne, "The Cartier-Stralak Area, District of Sudbury," Report of the Ontario Department of Mines, Vol. XXXVIII, Part VII (1929), pp. 52-68.

T. T. Quirke, "Geneva Map-Area, Sudbury District, Ontario," Geological Survey of Canada, Summary Report, Part D (1920), pp. 7-18.

³Carl Tolman, "The Birch Lake Batholith, Ontario," AJS, 5th Ser. XVII (1929), 403-424.

The majority of these rocks are altered diabase, which appear to have been intruded shortly after the batholith while it was still very hot. In later times, the area has been deeply eroded and, more recently, glaciated.

PRE-HURONIAN

Pre-Huronian rocks border the Birch Lake batholith in the southeastern part of the area mapped, as shown in Figure 2. Near the contact, the only place where they were seen, they are chiefly gneiss.

HURONIAN SEDIMENTARY ROCKS

Three areas of Huronian sedimentary rocks, referred to hereafter as the northern, southern and western areas, are found in Hart township; the first two were mapped quite carefully (Fig. 2). A fourth area, shown as a narrow strip along the railway in the northern part of the map (Fig. 2), was examined by Dr. W. H. Collins (accompanied by the writer) and mapped by him. In the southern area a section was discovered extending from just below the top of the Mississagi formation up into the Gowganda formation. It corresponds so closely both lithologically and stratigraphically to the Huronian section on the north shore of Lake Huron,⁴ that considerable confidence is felt in correlating the two. In the northern area, the Bruce series is represented only by remnants of the Bruce limestone and Espanola greywacke. The Serpent quartzite is absent presumably having been removed by pre-Cobalt erosion. Both the Gowganda and Lorrain are well represented here.

STRUCTURE OF THE HURONIAN SEDIMENTARY ROCKS

Structurally, the southern area of Huronian sedimentary rocks is divided into two parts, an eastern, in which the structure is comparatively simple, and a western, in which it is complex and obscure. The rocks in the eastern part form a steeply-dipping

⁴W. H. Collins, "The North Shore of Lake Huron," Geological Survey of Canada, Mem. 143 (1925), pp. 30-67.

homoclinal structure broken by two small faults, one near each end. West of this structure, just north of the township line, there are a few outcrops which display features seen elsewhere in the area only in the Espanola formation. These rocks are believed to be separated from those of the Gowganda formation to the east by a fault.

The distribution of formations in the northern area may be accounted for in several ways. The simplest explanation and the one which fits the field evidence best is that the Gowganda formation in the western part of the area is separated from the Lorrain and other formations in the eastern part by a fault.

THE BIRCH LAKE BATHOLITH

Previous Work

In 1923, Bain mapped the southerly part of the Birch Lake batholith as "Killarney granite."⁵ The area was again examined in 1926 and 1927 by Tolman and the known limits of the batholith extended north to the big bend in the Spanish River without finding its northern contact. Both he and Bain found that it intruded the Huronian series and some later basic intrusives, but was itself intruded by quartz bearing basic intrusives and by olivine diabase. The rocks as Tolman describes them appear to be practically identical with those in Hart township.

The northern boundary of Tolman's work is within a few miles of the Geneva area which Quirke had mapped in 1920.⁶ Quirke divides the granitic rocks of the area into two groups, pre-Huronian and Keweenawan (?). The former is chiefly alaskite; the latter is chiefly porphyritic syenite. Nowhere was the contact between these two rocks defined although an assumed contact is shown in two places. Most of the batholithic rocks are not differentiated on his map.

In 1928, Osborne⁷ reexamined the Geneva area and extended the mapping for a few miles all around it, but did not quite connect with Tolman's work. He calls all the granitic rocks in the area, including the porphyritic syenite differentiated by Quirke,

⁵George W. Bain, "Tectonics of Original Huronian of Webbwood, Ontario," Pan-American Geologist, Vol. XLIV (1925), Fig. 3, p. 96.

⁶Quirke, op. cit.

⁷Osborne, op. cit.

"granites (largely pre-Huronian)".⁸

Petrography

The Birch Lake batholith underlies by far the greater part of the area shown in Figure 2. Its contact was found only in the southeastern part where it adjoins pre-Huronian gneiss. The rocks shown in contact with it in the northern part of the map are part of an area which may well be totally surrounded by the batholith.

The typical rock is alaskite. It is massive, medium grained, pink, low in mafic minerals, and has occasional feldspar phenocrysts. The color varies somewhat; both red and white phases being found here and there. Usually the phenocrysts are quite rare, but in places they are more abundant and in a few places are so common that they form nearly all of the rock, making it very coarse grained.

The rock is composed dominantly of potash feldspar, plagioclase and quartz, with small grains of biotite and apatite quite common in practically all sections, and zircon, rutile, titaniferrous magnetite, titanite and orthite occasionally seen. The plagioclase varies slightly in composition; the average composition is about $Ab_{90}An_{10}$. Most of it is somewhat altered to white mica and kaolin, sometimes in patches, but usually rather uniformly. The potash feldspar is represented by either orthoclase, microcline or both. Sericite is never formed in it, but kaolin is, though not as abundantly as in the plagioclase.

The rock appears to have undergone appreciable deformation. Strain shadows are very common in the quartz and a number of grains are broken into pieces, which extinguish at slightly different angles. In most sections a few fractured grains of feldspar can be found, many of the fractures being filled with chlorite, biotite or epidote. Sutured and interlocking boundaries are common especially between quartz grains.

Contact with the Huronian

The contact with the Huronian is, in general, straight or gently curving. Re-entrants or dikes of alaskite into the sediments are rare. Usually the alaskite near the contact does not differ appreciably from that in the main mass of the batholith, but in a few places particularly along the western side of the

⁸Ibid., map No. 38h.

northern area, phenocrysts are very common, making up to 75 percent of the rock. Contact metamorphic effects do not extend more than 10 feet into the sediments in most places.

If a plutonic rock is older than a sediment, the contact can be either an unconformity or a fault, and if it is the former, the base of the sedimentary series must be along the contact. If the plutonic rock is younger, the contact can be either an intrusive contact or a fault contact.

In the northern area of Huronian sediments, the Mississagi quartzite is absent; in the southern area only a small patch is present which ends in both directions along the strike by running into alaskite. Apparently, then, there are only about 500 feet of the contact which can possibly be an unconformity. Most of the contact, however, is clearly not an unconformity, so if the batholith is pre-Huronian, its contact with the Huronian sediments must be a fault contact in most places. The rocks have been seen within a few feet of the contact at several places where it is certainly not an unconformity, and though, at some, the sediments are greatly disturbed, at others neither the sediments nor the alaskite show any sign of unusual stress. If the contact were along a fault with a displacement big enough to bring pre-Huronian rocks against the Gowganda formation, at least 2500 feet above, the rocks next it would probably be considerably sheared. The faulting hypothesis also involves a remarkable number of faults. The contact is usually straight or gently curving which rather favors this idea, but in some places, it is quite crooked.

The above discussion presents the objections to believing the batholith to be pre-Huronian, that is, negative evidence favoring the opposite view. In addition, there is some good positive evidence. In the southwest corner of the southern area, two small dikes of alaskite were found in the sediments for short distances. They do not differ from the normal alaskite particularly. In the northern area, an outcrop of alaskite was found in the Gowganda formation. The rock is pink and porphyritic, with euhedral crystals, which are best seen on the weathered surface. Under the microscope, it is seen that grains of quartz, orthoclase, microcline and sodic andesine, about 1 millimeter across, make up about two-thirds of the rock and that the rest is a fine grained aggregate, chiefly calcite and plagioclase more sodic than that

in the large grains.

The Western Area

At one place in the western area, the sedimentary rocks dip at 60 degrees toward alaskite, which is exposed a few feet from them, indicating that the contact is not an unconformity. Since the rocks here are not especially deformed, it appears that it is not a fault-contact. The only remaining possibility is that the alaskite intrudes the sediments.

North of Cartier

Alaskite, similar to that in Hart township, is exposed in contact with Huronian sediments on the railway about two and one-half miles north of Cartier, a place mentioned by both Quirke and Osborne. It was examined by Dr. Collins (accompanied by the writer), who expressed the opinion that the formation in contact with the granite, there, is conglomerate of the Gowganda formation and that the formations encountered, proceeding northward from it, are (in order) Serpent quartzite, Espanola greywacke, Espanola limestone, Bruce conglomerate and Mississagi quartzite; that is, the top and not the base of the succession is toward the granite. The contact, therefore, is either along a very big fault or is an intrusive contact; the absence of more than ordinary deformation indicates that the latter alternative is correct.

Similar alaskites were seen at many places between here and the northern area of Huronian sedimentary rocks in Hart township, so it is probable that the rocks at the two places form part of the same mass.

Probable Extent of the Birch Lake Batholith

The southern contact of the batholith was traced for about 14 miles approximately north 60 degrees east from the eastern edge of the map, Figure 2. About 14 miles further in this direction, along the Vermilion River, strongly folded sediments of the Cobalt series are encountered. The intensity of folding decreases toward the northeast, till beyond Sturgeon River where the dips are only 0 to 30 degrees. This condition continues to Gowganda about 40 miles north and to Lake Timiskaming about 50 miles east.⁹ This

⁹W. H. Collins, "Onaping Map-Area," Geological Survey of Canada, Mem. 95 (1917), p. 78.

suggests a large post-Huronian intrusion to the southwest at no great distance. The nearest place where granite is described as intruding the Huronian is on Lower Onaping Lake, where Quirke found a "syncline containing Huronian rocks bounded on the south, east and part of the northern sides by faults and on part of the northern side by acid intrusions."¹⁰

Alaskite, similar to and apparently continuous with that in Hart township, is found a few miles east of the Aux Sable River from 3 to 20 miles north of Massey. Just north of the Forestry tower near this river, 16 miles north of Massey, a small patch of Mississagi (?) quartzite was found, apparently lying unconformably on the alaskite.¹¹

Comparison of the Birch Lake Batholith
with Other Killarney Granites

The descriptions¹² of granite masses, whose intrusive relations to Huronian sedimentary rocks is well established, shows that there are a number of important characteristics, each of which is found in most if not in all of them. It appears that potassic feldspar, accompanied by oligoclase, is abundant, feldspar phenocrysts are quite frequent, mafic minerals are not common, and the rocks are red rather than gray. The various bodies are, as a rule, notably uniform throughout their extent and gneissic structures are very rare, except in the Killarney batholith.

The rocks of the Birch Lake batholith display the same general features as the other Killarney intrusives, but the following minor differences are apparent. The plagioclase is slightly more alkalic, mafic minerals are present in smaller amounts and quartz is rather more abundant.

¹⁰Quirke, op. cit., p. 17.

¹¹These observations were made while employed by the Bureau of Economic Geology and are published with the permission of the director.

¹²Collins, op. cit., pp. 86-87.
R. G. McConnell, "Sault Ste. Marie Area," Ontario Bureau of Mines, Vol. XXXV, Part II (1926), pp. 38-40.
E. L. Bruce, "Geology of the Townships of Janes, McNish, Pardo and Dana," Ontario Bureau of Mines, Vol. XLI, Part IV (1932), pp. 24-25.

BASIC INTRUSIVES

All the basic igneous rocks found in the area are included in this section, whether or not they can be shown to intrude the Birch Lake batholith. The majority of them are altered diabase, the remaining few being olivine diabase, perknite and lamprophyre.

Altered Diabase

The altered diabase forms numerous small dikes and masses throughout the area, and three sills of considerable size in the Huronian rocks or along their contact with the granite.

The majority of these rocks are massive and equigranular. They vary in texture from medium-grained to dense, the grain-size increasing, in general, with the size of the body and the distance from the wall. The coarser varieties contain about equal proportions of dull white and shiny black grains. As the grain-size decreases, the proportion of white mineral decreases till, when the grain-size is about one-quarter millimeters, the rock appears to be a uniform mass of minute shiny black needles with no light colored grains at all. Further decrease in grain-size finally results in a dense, black rock, extremely hard and strong.

In thin section, the rock is found to consist dominantly of hornblende, chiefly secondary, and plagioclase in nearly equal proportions. Quartz and magnetite are prominent in some sections. Plagioclase ranges from medium labradorite to calcic sodaclase. All the specimens are greatly altered. Among the secondary minerals actinolite and epidote are abundant, chlorite and leucoxene are fairly common and white mica is present in a few sections. Twenty sections were arranged in order of increasing albite content in the plagioclase and examined to see if other changes could be related to this. The specimens were fairly uniformly distributed, except near the albite end where they were more numerous.

At the labradorite end of the series, the feldspar crystals are glassy and nearly free from inclusions of secondary minerals. As the plagioclase becomes more sodic, inclusions increase in number, till, at the albite end, it is crowded with actinolite and epidote, but is still glassy in the parts between them. The hornblende grains become increasingly irregular in outline and patchy in appearance toward the albite end of the series and small

needles of secondary amphibole get more and more numerous in the feldspar. A blue color which is seen only on the borders of the grains in specimens at the labradorite end spreads into the grains and gets stronger progressively along the series. Biotite is found in a few of the intermediate members of the series as roughly equidimensional grains and is quite common as small irregular grains in several specimens from the albite end. In a few specimens the mafic minerals are almost entirely altered to chlorite, but, as a rule, this mineral is quite scarce. Epidote, in general, is more abundant toward the albite end of the series, and the grains are larger. Quartz is not always present in specimens from the labradorite end, but is found in all specimens from other parts of the series although it rarely exceeds 5 percent. Magnetite is quite fresh at the labradorite end, but soon narrow rims of leucoxene appear and become steadily wider till at the albite end there is little magnetite left.

The proportion of feldspar to hornblende varies somewhat in different specimens, but there does not seem to be a progressive change. The increasingly sodic character of the plagioclase and amphibole indicates that some soda has been added to the rock. Since the more sodic plagioclase is more silicic and since there is a slight increase in the amount of quartz, a considerable amount of silica must have been added. Part of the lime, released by the breakdown of the anorthite molecule, appears to have been lost and the balance has gone to form epidote and leucoxene. The amounts of the other oxides in the rocks seem to be essentially unchanged.

The texture, though greatly modified in detail by the changes described above, is, in general, the same throughout the series.

It is not certain whether the primary mafic mineral was hornblende or augite or if both were present. There is a little evidence indicating that each of these minerals was primary. However, as the dark mineral in rocks of ophitic texture, with approximately equal amounts of light and dark minerals, is commonly augite rather than hornblende, it seems probable that augite is the chief primary mafic mineral in these rocks. Accordingly the name diabase is appropriate.

Character of the Alteration

From the gradational character of the changes, and from the similarity of texture and bulk composition throughout the series, it is concluded that all of these rocks are members of the same group of basic intrusives and have all been subjected to the same type of alteration, but in varying degrees. It was mentioned that in a few specimens scattered through the series, chlorite is abundant. This is attributed to another type of alteration, superimposed on the first.

The main alteration appears to have involved the addition of soda and silica to the rock and the removal of lime. It is inferred from the abundance of secondary hornblende and actinolite that it took place at a high temperature, at least equal to that under which hypothermal ore deposition takes place.¹³ The temperature of formation of this class of ore deposit is believed to be "300° C. - 500° C. $\pm$."¹⁴

Relation to the Birch Lake Batholith

The altered diabase forms dikes and masses of irregular shape in the alaskite. They are believed to be intrusive, because they are, in many cases, chilled along their borders and because numerous inclusions of the wall rock are found in them. On the other hand, the bodies within the batholith are much more altered than those in the alaskite-gneiss contact zone, indicating clearly that the batholith exerted some control over them. This, together with the high degree of alteration of the altered diabase masses compared with the comparatively fresh appearance of the alaskite, would ordinarily be interpreted as showing that the former are actually inclusions not intrusive masses.

To harmonize these apparently conflicting lines of evidence, another interpretation must be found for one of them. It is suggested that the diabase magma was intruded, while the alaskite was still so hot that residual solutions were abundant in it and that these caused the alteration of the diabase. If this is

¹³In the paragenesis tables used by E. S. Bastin in his classes, the least intense conditions under which hornblende or actinolite can form is given as "deep H T." -- (hydrothermal)

¹⁴W. Lindgren, *Mineral Deposits* (3rd ed.; New York: McGraw Hill Book Co., Inc., 1928), p. 238.

correct, the temperature of the alaskite must have been at least 300°C . to produce the type of alteration found in the diabase. The irregular form of the altered diabase bodies lends some support to the view that the alaskite was very hot at the time of their intrusion, since it would then be more plastic and less likely to fracture in long clean-cut fissures.

The existence of chilled contacts, at first thought, is distinctly adverse to this hypothesis. However, the temperature of the diabase magma can scarcely have been more than a few degrees below 800°C .¹⁵ and may have been much higher.¹⁶ Even if the magma temperature were only 800°C . it would be 500°C . hotter than the walls, whereas if the granite had completely cooled the difference in temperature would only be about 750°C . If the magma is strongly chilled on coming in contact with a wall 750°C . cooler than it is, it seems reasonable to suppose that the chilling produced if the wall is 500° cooler will be quite pronounced.

Comparison with Other Dikes in the Region

Tolman describes numerous, somewhat irregular, dikes,¹⁷ which intrude the part of the Birch Lake batholith south of Hart township, as consisting chiefly of hornblende, sodic albite, and, in most cases, some biotite, each of which sometimes occurs as inclusions in the others. The amount of hornblende varies between 35 and 80 percent. Epidote apparently is not abundant. These dikes are greatly altered and there is no evidence as to the nature of their original structure or minerals. It is possible that they are members of the altered diabase series just described, being more altered than any of those examined by the writer.

It seems quite possible that these intrusives are altered members of the post-Cobalt series of quartz-diabase dikes and sills

¹⁵T. A. Jaggar, "Volcanologic Investigations at Kilauea," *AJS* (1917), p. 214. Jaggar actually measured the temperature of the lava of Kilauea three feet below the surface and found it to vary between 750°C and 850°C .

¹⁶R. A. Daly, Igneous Rocks and the Depths of the Earth (New York: McGraw Hill & Co., Inc., 1933), p. 303. Daly quotes several estimates of the temperatures of basic magmas which vary from 1170°C . to 1400°C . These estimates are based on the effects of the magma on inclusions.

¹⁷Tolman, op. cit., pp. 420-423.

which are so abundant and widespread in the region. These consist¹⁸ of labradorite and augite in approximately equal proportions, and, in the coarser phases, a granophyric intergrowth of quartz and feldspar between the other grains. The texture is always ophitic. Most writers say little about the alteration of the rocks, so it is presumably not great. However, in a few cases, it is considerable, the augite being altered to hornblende.

Olivine Diabase

A few olivine diabase dikes, similar to those found elsewhere in the region,¹⁹ were found near the alaskite-gneiss contact. One of them cuts an altered diabase dike nearly at right angles in lot 7, concession III, Cartier township, about 200 yards southwest of the railway. The altered diabase dike makes a pronounced ridge in which there is a deep notch on the line of strike of the olivine diabase dike, from which it is concluded that the latter is younger than the former and consequently younger than the Birch Lake batholith.

CORRELATION OF THE IGNEOUS ROCKS

The oldest post-Cobalt igneous rocks in the district along the north shore of Lake Huron are quartz diabase dikes and sills. These are followed by Killarney granites which, in turn, are followed by olivine diabase dikes. In the vicinity of Hart township the succession is, starting with the oldest, Birch Lake batholith, altered diabase, olivine diabase. The question is whether to correlate the batholithic rocks or the quartz diabase and the altered diabase. The first alternative seems more

¹⁸N. L. Bowen, "Diabase and Granophyre of the Gowganda Lake District, Ontario," Journal of Geology, XVIII (1910), 658-674.

W. H. Collins, "Geology of the Gowganda Mining Division," Geological Survey of Canada, Mem. 33 (1913), pp. 59-83.

W. H. Collins, "Onaping Map-Area," Geological Survey of Canada, Mem. 95 (1917), pp. 84-101.

W. H. Collins, "North Shore of Lake Huron," Geological Survey of Canada, Mem. 143 (1925), pp. 77-82.

Hurst, op. cit., p. 60 f.

E. S. Moore, "Ore Deposits near the North Shore of Lake Huron," Ontario Bureau of Mines, Vol. XXXVIII, Part VII (1929).

Bruce, op. cit., p. 18.

¹⁹Collins, op. cit., pp. 82-84.

probable since the rocks of the Birch Lake batholith are very much like those of other Killarney batholiths, whereas, due to uncertainty as to their original character, the altered diabase cannot be said to resemble the quartz diabase.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. W. H. Collins and Dr. E. D. Kindle for their aid in the field work. Acknowledgment is also due the Geological Survey of Canada for the use of camp equipment. Some of the observations on the extent of the Birch Lake batholith were made during the summer of 1935, while the writer was employed by the Bureau of Economic Geology and are published with the director's permission.

The aid of Dr. Albert Johannsen in the microscopic work and in the preparation of the parts on igneous rocks and of Dr. R. T. Chamberlin on the parts on stratigraphy and structure is gratefully acknowledged. The clearness of the maps has benefited greatly from the suggestion of Dr. F. J. Pettijohn.



